

# Ka band active array antenna for mobile satellite communications

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**Abstract** - This paper describes a modular active antenna for satellite communications in the K/Ka band. The application is thought for mobile satellite communications and internet links, mainly for commercial airplanes. The impossibility to build full active antennas, including amplifiers in all the elements, leads to a modular semi active antenna. Here the module is a small subarray with complete phase control in the elements. The phase control is made with ad-hoc phase shifters giving the minimum losses. Only two-bit control has been selected to perform phase shifters associated to a circular polarization radiating element. The feeding network has been selected to minimise the losses and the gap waveguide has been designed to perform the network. The radiating element is a circular double patch fed into two points to obtain circular polarization. The entire prototype has been designed in LTCC substrate to minimise the losses and stabilise the structure.

**Index Terms** — Phased Array Antennas, Ka Band, Satellite Communications.

## 1. Introduction

The specifications for Ka band satellite communication antenna systems lead to large antenna gain in the ground terminal [1], [2], [3]. As presented in a previous communication [4], there exists an important restriction in the antenna design for mobile terminals. The main beam direction electronic control must be large and is required to include phase shifters and amplifiers associated to each element in the array. On the other hand, a high gain is required in the antenna force to perform a large antenna size and, most importantly, a large number of radiating elements, reaching values of several thousands. The large number of active circuits to be included in the antenna makes the active antenna implementation physically and economically impossible.

The option presented here is dividing the antenna into passive subarrays, with the minimum possible losses, in order to drastically reduce the number of active integrated circuits like amplifiers or phase shifters. Some phase control is needed at the radiating element level and one of the problems is how to obtain information about the losses added in these situations. Here we study the option of several passive subarrays with some control in the main beam direction. Also the circular polarization switch must be implanted at this level.

Although many papers have been published about the design and fabrication of Ku and Ka band antennas for mobile-satellite communications; few commercial antennas

have been done with full phase control in the radiating elements [5], [6], [7]. Some of the commercial antennas seen in the web pages of several companies ensure their success in the construction but do not offer information about the way or the electronics used to do it [8], [9], [10].

## 2. Passive subarrays

The proposal is a passive subarray with a variable number of elements from  $2 \times 2$  to  $8 \times 8$  as a maximum. This range has been selected as a function of the antenna size to obtain the required antenna gain. To satisfy the gain over noise temperature conditions of  $G/T=12\text{dB/K}$  for the receiving antenna at 20 GHz, a minimum antenna gain, around 35dBi, has been estimated for a typical 2dB noise figure amplification associated to each element. To cover the pointing capacity of  $60^\circ$  from the broadside, the minimum size of the antenna is around  $0.5 \times 0.5 \text{ m}^2$ . Any additional losses due to phase shifters or passive feeding network increase the size and the number of elements in the antenna. Table I compares the size of the antenna for several passive subarray configurations.

TABLE I  
Subarray size comparison

Subarray size	Added Network losses [dB]	Array size [ $\text{m}^2$ ]	Total number of elements	Number of subarrays
None	0	$0.5 \times 0.5$	4096	-
$2 \times 2$	1	$0.6 \times 0.6$	5476	1369
$4 \times 4$	1.6	$0.68 \times 0.68$	7056	441
$8 \times 8$	2.4	$0.84 \times 0.84$	10816	169

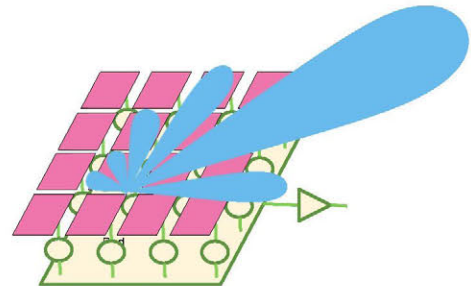


Fig. 1. Subarray schematic circuit.



As the subarray number of elements grows the loss factor due to the distribution network takes higher values and the total size of the antenna must be larger to compensate these losses. On the other hand, the number of subarrays and the number of active integrated circuits needed to build the antenna is lower and cheaper.

### 3. Radiating element

The circular polarization specified for the antenna includes the option to switch the polarization sense from RHCP to LHCP. To perform this specification a circular printed patch, fed by a metalized via, has been selected as a radiating element. The bandwidth is broadened with a parasitic patch and the coupling to the neighbour elements is minimized with a metallic cavity. Both patches are implemented in a printed circuit over dielectric substrates keeping an air layer in between. The cavity in that air layer is achieved by using a mechanized metallic sheet.

Figure 2 shows the layers in the antenna element. The feeding is performed through a metalized via to connect the printed strip line to the patch through the ground plane.

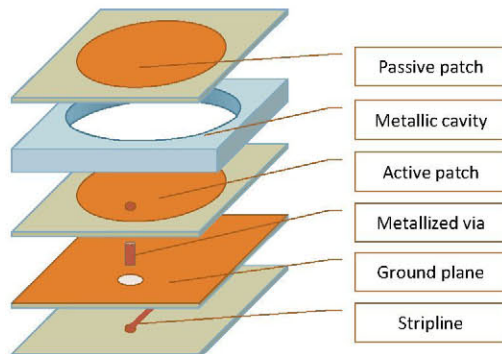


Fig. 2 Printed patch fed with strip line.

Figure 3 and figure 4 show the antenna patch main response.

### 4. Phase shift circuit

To get the appropriate phase at each array element in the main beam pointing process, we need a phase sifter attached at each radiating element. These phase sifters must support minimum losses to avoid gain reduction. To reach this goal a two bit phase sifter has been designed. It is based on several switches (PIN diodes, MEMS ...) to select the feeding point in the printed patch.

Mainly in directions far from the main beam, two bit phase control is not enough to get a low side-lobe level pattern. To avoid grating lobes and prevent strong jumps in the main beam direction in the pointing process, a random phase has been added in the phase discretization process. This process allows working with a random phase term in the array aperture, lowering the antenna directivity a few tenths of a dB [11].

It can be seen that the high phase error discretization produces high grating lobes associated to the subarray structure. The lobes are farther from the main lobe in small subarrays but their level is lower for large subarrays.

### 5. Feeding network

The subarray feeding structure is especially important to reduce losses as much as possible. Several transmission lines have been studied to perform this structure. Simulations have been done with two dielectric materials: A dielectric substrate like Rogers RO 4003 and a ceramic LTCC substrate like Dupont 9K7V.

### 6. Conclusion

High gain phased array antennas at high microwave frequencies or millimeter waves require a large number of elements and a high cost when each element is driven with a low noise amplifier and a phase sifter. The connection of these circuits and the associated control circuits in a very small size radiating element is also very difficult. To make the antenna viable, passive subarray modules have been designed. The phase control has been limited to two bit phase shifters and the transmission line has been selected to reduce, as much as possible, the distribution losses. Simulations of all these circuits have enabled a design that we expect to show in the conference.

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